Polymer Processes in a Diffusion Controlled Environment

Project Number: 95-16

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Purpose

To conduct polymerization processes on the KC–135 in order to study the effect of convection on polymerization products.

Background

Polymerization processes typically involve chemical reactions in which large gradients in temperature and solutal concentrations develop. The initial solutions are typically of a viscosity similar to water and therefore double diffusive convection is inevitable. The final products are frequently highly entangled, glassy materials of near infinite viscosity, trapped in a nonequilibrium state. Thus, the final properties of the material obtained are often the result of the kinetics of the heat and mass transfer processes associated with the production of the material. The goal of the project is to determine potential uses of microgravity for the study of polymer processing and research.

In the first year of research, neat-free radical photo polymerizations of methyl methacrylates (MMA) were performed. It was found that the molecular weight distributions were broader, the average molecular weights were greater, and the conversions were lower in the microgravity samples. This result is consistent with a reduction in polymer chain termination relative to growth and a general slowing of mass transport. The results were also consistent with reports from a German group which did drop tower research. Co-polymerizations of polymer ethylene glycol methacrylates and MMA did not show a difference in monomer ratio in the final product, thus indicating a depletion zone of the more reactive monomer did not develop around the growing chain ends. This may be due to high mobilities of the chain ends since the reactions were done at low conversions, about 10 percent.

The subsequent focus of the project has become to study the formation of networks formed by photopolymerization. Network formation is particularly susceptible to a phenomenon known as the Tromsdorf effect. This occurs when the growing polymer chains become so long that their mobility plunges rapidly. This in turn leads to a great decrease in the molecular events in which the growth of the chains terminates. Thus a rapid increase in the rate of polymerization occurs. This process is often referred to as autocatalysis and is crucial to the properties of the material produced.

Polymer dispersed liquid crystals (PDLC's) were chosen for the studies because they are of industrial importance and easily characterized. The liquid crystalline material is miscible in the monomer but immiscible in the polymer. As the polymerization proceeds, the liquid crystal phase separates and forms islands within the polymer network. PDLC's are used for such devices as calculator displays, since certain liquid crystals (which are opaque to light due to random molecular ordering) can be made transparent when placed in an electric field. This causes the molecules to align.

Approach

Free radical photopolymerizations are performed on the KC–135 using an ultraviolet light source.

Accomplishments

In this year, two KC–135 flights were performed in which PDLC samples were produced. The PDLC's were studied by scanning electron microscope (SEM) at USM, and the materials were subjected to an electric field in order to study response characteristics. The liquid crystal droplets were found to be approximately 1 micron in diameter in the microgravity samples verses 2 microns in the ground control. In significant respects, the microgravity samples appear to be of better quality than the control samples. As can be seen in the figure, the microgravity sample is more opaque prior to being exposed to a field, and has a faster and sharper response both to the turning on of the field and the removal of the field. There is no significant difference in the transmission between the two samples. The results are consistent with the SEM observations that the microgravity samples are smaller and more uniform and, therefore, would be expected to provide a better response. A number of other samples are currently undergoing similar testing at USM.

Planned Future Work

USM is expected to complete their studies of the existing flight samples in the next 2 months. USM has responded to the 1997 Materials NASA Research Announcement proposed to study PDLC produced on the KC–135. NASA and USM may pursue commercial product development funding.

Publications

Whitehead, J.B., Jr.; Chandler, M.M.: *Proceedings of the SPIE*, Vol. 3123, Materials Research in Low Gravity, pp. 128–134, 1997.

Funding Summary ($k)

All funds authorized for this project (46k) are now costed.

Status of Investigation

The project was authorized in August of 1994. The project will be complete when the characterization of materials produced on the KC–135 is complete. The estimated completion date is January 1998.